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Original Article

The comparison of ultrasound, chest X-ray, and chest CT in the diagnosis of pneumothorax in thoracic trauma patients

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ABSTRACT

Aims: Pneumothorax (PTX) is a critical condition frequently encountered in thoracic trauma that requires prompt diagnosis and management. This study aimed to compare the diagnostic accuracy of ultrasound (USG), chest X-ray (CXR), and thoracic computed tomography (CT) in detecting PTX in patients with thoracic trauma.

Methods: A prospective study was conducted on patients presenting to the emergency department with thoracic trauma. Each patient underwent an initial USG examination using the Extended focused assessment with sonography for trauma (E-FAST) protocol, followed by CXR and CT. The sensitivity, specificity, and diagnostic accuracy of USG and CXR were evaluated using CT as the reference standard.

Results: CT confirmed PTX in 15 cases (13%) among the studied patients. USG demonstrated a sensitivity of 73.3% and a specificity of 100%, while CXR showed a sensitivity of 0.0% and a specificity of 98.7%. The diagnostic accuracy of USG was significantly superior to that of CXR.

Conclusion: USG is a highly specific and efficient bedside tool for diagnosing PTX in thoracic trauma patients. Its implementation in emergency settings can facilitate early detection and management, particularly when CT is unavailable or delayed.

Keywords: Pneumothorax, ultrasound, chest X-ray, computed tomography, emergency department

INTRODUCTION

Traumas are a significant public health problem, especially affecting the young population. In Turkiye, the most common causes of trauma-related deaths are traffic and occupational accidents.[1,2] According to the World Health Organization, 200.000 people die annually due to motor vehicle accidents, and 6 million people are injured.[3] In the United States, 20-25% of trauma-related deaths are due to thoracic trauma, resulting in approximately 16.000 deaths each year.[3,4]

Approximately one-third of trauma cases requiring hospitalization involve thoracic trauma. Early diagnosis, appropriate resuscitation, and rapid intervention can significantly reduce mortality in these patients.[5] Thoracic trauma most commonly occurs due to motor vehicle accidents, stab wounds, and gunshot injuries. In Turkiye and our region, thoracic trauma due to traffic accidents is increasingly common. One of its most prevalent consequences, pneumothorax (PTX), has been reported at varying rates between 20% and 35% in different series, depending on the severity of the trauma.[6,7]

Conventional diagnostic methods for PTX include chest X-ray (CXR) and computed tomography (CT), with CT being considered the gold standard.[6] However, ultrasound (USG) is increasingly utilized and recommended in guidelines due to its advantages, such as being radiation-free, non-invasive, and rapidly applicable at the bedside.[8,9] First used for PTX diagnosis by Wemeck et al.[8] in 1987, USG has gained attention for its effectiveness in early diagnosis.

This study aims to evaluate the effectiveness of USG in diagnosing traumatic PTX by comparing it with CT, which is accepted as the gold standard.

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METHODS

Study Design and Scope

This thesis study was conducted on patients who presented to the emergency department of Ankara Atatürk Training and Research Hospital due to thoracic trauma between June and July 2013. The study was conducted before 2020, and institutional approval was obtained. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. The inclusion criteria covered 116 patients who underwent an USG examination for PTX evaluation as part of the E-FAST protocol in the trauma room upon hospital admission, followed by CXR and thoracic CT.

Exclusion Criteria

Patients who were not included in the study were:

Those who had no detectable cardiac activity upon hospital arrival,

Those who did not undergo thoracic CT due to lack of indication,

Those who presented with iatrogenic thoracic trauma,

Those who had a chest tube placed based on physical examination, USG, and CXR findings, thereby not undergoing thoracic CT.

Ultrasound (USG) Application Protocol

For approximately two years, bedside USG has been performed in trauma patients by emergency medicine residents trained in USG at our hospital. In this study, a Mindray UMT-200 USG device with a 7.5 MHz linear probe was used for PTX detection.

During the evaluation, the second and fourth intercostal spaces in the midclavicular line of both hemithoraces were examined. In M-mode imaging, patients who exhibited the absence of the "seashore sign" were diagnosed with PTX. After diagnosis, patients underwent CXR and, when indicated, thoracic CT.

Data Collection and Evaluation

Patients included in the study were retrospectively analyzed based on the following parameters:

Gender,

Age,

Type of trauma,

Etiology of trauma,

Associated injuries.

USG findings were compared with the interpretations of CXR and thoracic CT images by radiology specialists.

Statistical Analysis

The data analyses were performed using SPSS version 17.0. Categorical variables were presented as frequency and percentage, while continuous variables were expressed as mean±standard deviation (or median, minimum–maximum where appropriate). The Chi-square test was used to compare CT and gender. Normality analysis was performed for continuous variables; since age exhibited a non-parametric distribution, the Mann-Whitney U test was used. Taking CT as the gold standard, the diagnostic values of USG and CXR were compared by calculating their sensitivity and specificity. A p-value of <0.05 was considered statistically significant for all tests.

RESULTS

Demographic and Clinical Characteristics

Of the 116 patients included in the study, 35 (30.2%) were female and 81 (69.8%) were male, with a mean age of 44±20 years. Blunt trauma was present in 113 cases (97.4%), while 3 cases (2.6%) had penetrating trauma. All patients with penetrating chest trauma were male. The most common causes of trauma were falls from height (46.6%) and motor vehicle accidents (40.5%), followed by occupational accidents (5.2%), stab wounds (2.6%), pedestrian-vehicle accidents (2.6%), and assaults (2.6%) (Table 1).

Table 1. Trauma etiology

Cause of presentation	Number	Percentage %
Fall	54	46.6
Motor vehicle accident-passenger	47	40.5
Work accident	6	5.2
Sharp-penetrating object injury	3	2.6
Motor vehicle accident-pedestrian	3	2.6
Physical assault	3	2.6

Associated Injuries

The most frequently observed additional injury due to trauma was head trauma, found in 24 patients (20.7%). Upper extremity injuries were present in 12 patients (10.3%), lower extremity injuries in 4 patients (3.4%), vertebral injuries in 2 patients (1.7%), and abdominal injuries in 1 patient (0.9%) (Figure).

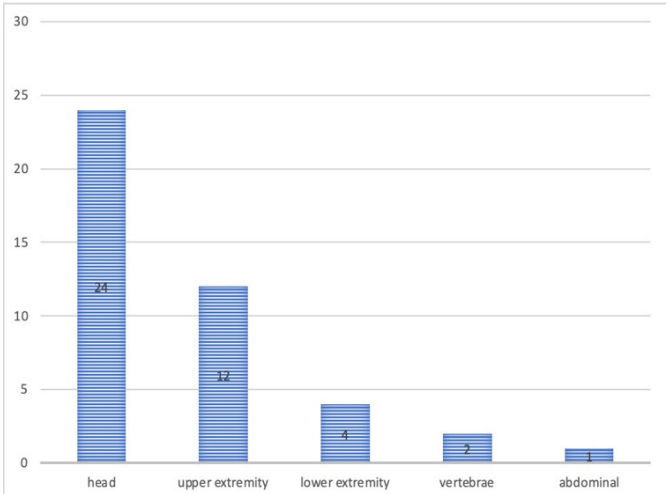

Figure. Additional injuries

Pneumothorax Detection and Comparison of Diagnostic Methods

Thoracic CT, accepted as the reference test, detected PTX in 15 of the 116 cases (13%). USG correctly identified PTX in 11 of the 15 cases detected by CT and also correctly classified 101 cases as normal. The sensitivity of USG was calculated as

73.3%, specificity as 100%, and overall accuracy as 96.5%. The average application time ranged from 2 to 3 minutes (Table 2).

Table 2. USG sensitivity and specificity

	Chest CT PTX					
	No	Yes	Sensitivity	Specificity	Accuracy rate	Kappa value
USG PTX						
No	101	4	73.3%	100%	96.5%	82.7%
Yes	0	11				

USG: Ultrasound, CT: Computed tomography, PTX: Pneumothorax

On the other hand, CXR was insufficient for PTX diagnosis, as it failed to detect PTX in any of the 15 cases identified by CT. However, CXR correctly classified 101 cases as normal, which had also been confirmed as normal by CT. The sensitivity of CXR was 0.0%, specificity was 98.7%, and overall accuracy was 87.1% (Table 3).

Table 3. Chest X-RAY sensitivity and specificity

	Chest CT PTX					
	No	Yes	Sensitivity	Specificity	Accuracy rate	Kappa value
X-RAY PTX						
No	101	15	0.0%	98.7%	87.1%	-
Yes	0	0				

CT: Computed tomography, PTX: Pneumothorax

DISCUSSION

The early diagnosis of traumatic chest injuries, particularly the rapid identification of PTX, is a crucial part of clinical management. PTX is a common condition following trauma and can lead to serious complications if not promptly addressed. Traditional diagnostic methods, such as CXR and CT, have been predominant; however, USG has increasingly been used in recent years as a fast, non-invasive, and radiation-free alternative.[8,9]

A study conducted in Turkiye showed that traumatic chest injuries were divided into 20-40% penetrating injuries and 60-80% blunt injuries.[10] Our study's findings do not align with the literature, and this could be attributed to the fact that our study was conducted in a non-specialized hospital and also due to the absence of a dedicated chest surgery unit at our center.

In our study, the most common trauma etiology was falls (46.6%), followed by traffic accidents (40.5%). Literature reports traffic accidents as the most common etiology at 31.3%.[11] In our case, falls and traffic accidents accounted for 93.2% of cases. This can be explained by the fact that our center typically receives multi-trauma patients rather than isolated chest trauma cases, such as those from stab or cut injuries.

In the study by Çobanoğlu et al.,[12] the most common accompanying injuries to chest trauma were extremity injuries (25.4%) and abdominal injuries (7.2%). Head injuries were observed in 10% of cases. In contrast, our study found that head trauma (20.7%) and extremity injuries (13.7%) were the most frequent accompanying injuries. Spinal injuries (1.7%) and abdominal injuries (0.9%) were less commonly observed. These findings are consistent with the general trend in the literature, indicating that chest trauma is typically associated with multi-trauma, and the frequency of accompanying injuries may vary.

The evaluation of the chest with USG has gained prominence in recent years and is now included in the ATSL guidelines for diagnosing conditions such as pleural effusion, hemothorax, and PTX. The first use of US for PTX detection was published in 1986 in a veterinary journal, followed by Wemeck et al.'s[8] 1987 study, which demonstrated the use of US in PTX detection. A large study conducted in 2001 evaluated 382 chest trauma patients using US, correctly identifying 37 out of 39 PTX cases, resulting in a sensitivity of 94%. False-negative results were attributed to subcutaneous emphysema, with no false-positive cases observed.[13] In a 2004 study by Knutson et al.,[14] US was shown to be a highly effective method for PTX detection with a specificity of 99.7%. US also plays a valuable role in penetrating trauma cases.

In a study by Nandipati et al.[15] in 2011, US showed a sensitivity of 95% and specificity of 99%, yielding superior results compared to chest CT. In contrast, CXR showed a sensitivity of 79% and specificity of 99%. In our study, similar to Nandipati's findings, US showed higher sensitivity and specificity compared to CXR.

Zhang et al.[16] found that the average time required for US was 2.3±2.9 minutes, for CXR 12.4±6.7 minutes, and for chest CT 16.3±7.8 minutes, indicating that US is significantly faster. In our study, the US time was 3.0±2.0 minutes. While CXR and chest CT times were not specifically measured, taking into account the transfer and post-imaging evaluation times, it is evident that US is much quicker. Based on these findings, US is recommended for the early and accurate diagnosis of PTX in polytrauma patients.

CXR fails to correctly identify 30-40% of PTX cases.[14] In cases of occult PTX, especially under positive pressure mechanical ventilation, tension PTX can develop. In a study by Kirkpatrick et al.,[17] US showed higher sensitivity than CXR (48.8% vs. 20.9%), with both tests demonstrating high specificity (99.6% and 99.7%, respectively). In a 2020 study by Soldati et al.,[18] US identified 23 out of 25 PTX cases, with a sensitivity of 92% and specificity of 94%. CXR only detected 13 cases with a sensitivity of 52%. In our study, US had a sensitivity of 72.3%, with four out of fifteen PTX cases not detected. Unlike the studies of Kirkpatrick et al.,[17] our study did not find any false-positive results from US or CXR. CXR failed to identify PTX in all 15 cases. This suggests that CXR has limitations in detecting small pneumothoraces, which may have contributed to the lack of detection in our study. Additionally, pneumothoraces less than 2 cm in size were detected in less than 10% of CT scans in our study. At the end of the study, two patients with undiagnosed PTX required positive pressure mechanical ventilation, while the other thirteen were managed with observation.

In our study, the sensitivity of US for PTX diagnosis was found to be 72.3%, whereas CXR and CT showed a sensitivity of 0.0%, highlighting CXR's limitations in detecting small pneumothoraces. Additionally, US was shown to be a highly effective, fast, and non-invasive method for PTX diagnosis, particularly in multi-trauma patients. These findings

underscore the importance of strengthening the role of US in PTX diagnosis and its widespread use in clinical practice.

Limitations

This study has several limitations. First, being conducted in a single center may limit the generalizability of the findings. Second, USG examinations were performed by emergency medicine residents with varying levels of experience, which could affect diagnostic accuracy. Additionally, interobserver variability in ultrasound interpretation was not assessed. Finally, the relatively small sample size may have impacted the statistical power of the results. Future multicenter studies with larger cohorts and standardized training protocols are needed to validate these findings.

CONCLUSION

The study concluded that USG is an effective and reliable method for diagnosing traumatic PTX. Compared to chest CT, US has higher sensitivity and specificity, with a shorter application time, while still providing high accuracy. In contrast, the sensitivity of CXR in detecting PTX was found to be very low, highlighting the limitations of CXR in PTX diagnosis. Therefore, US can be used as a reliable and rapid alternative for PTX diagnosis in trauma patients, but it should be performed by experienced personnel to ensure accurate results. These findings support the widespread use of US in emergency departments, where quick and effective decision-making is crucial.

ETHICAL DECLARATIONS

Ethics Committee Approval

This thesis study was conducted before 2020, and institutional approval was obtained.

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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